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Biological Assessment and Ecological Risk Assessment
New Tools for Clean-Up Decisions at Hazardous Waste Sites

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16. ABSTRACT

Bioassessment techniques are useful tools that can be used to evaluate the toxicity of site-specific complex mixtures using resident or laboratory-raised organisms. Although regulations based on bioassessment have been implemented under the NPDES program, the use of these techniques at hazardous waste sites is at a relatively early stage of development. Most commonly, bioassessment techniques have been used to identify contaminated areas at sites, and also to measure adverse effects that have occurred at the site. In order for bioassessment to be more extensively used, however, advances are needed in two general areas. First, we need to provide firmer links between endpoints that can be measured via bioassays (e.g., death of a caged organism) to endpoints that are used in decision-making (e.g., decline of a natural population). Second, bioassessment results need to be more directly applicable to the design of treatment technologies. In this way, bioassessments can be used not only to document adverse effects, but also to provide input into the decisions regarding what should be remediated, and how much remediation should occur.

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BIOLOGICAL ASSESSMENT AND ECOLOGICAL RISK ASSESSMENT:

NEW TOOLS FOR CLEAN-UP DECISIONS AT HAZARDOUS WASTE SITES

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INTRODUCTION

The goal of EPA's Superfund program is deceptively straightforward -- find the nation's worst abandoned hazardous waste sites and clean them up. Achieving this goal in a logical and defensible manner has proven to be a much more difficult task. The initial strategy of the program has emphasized monitoring and testing the toxicity of individual chemicals. However, there has been renewed interest in testing site-specific complex mixtures and organisms. Biological assessment techniques are particularly useful for these purposes and hence have great potential for supporting decisions made at Superfund and other hazardous waste sites.

A wide variety of tests and measurements are referred to as bioassessment techniques. They include the following:

- conducting toxicity tests on contaminated environmental media brought into the laboratory;
- using biochemical characteristics of organisms (biomarkers) to estimate exposure or toxic response;
- conducting toxicity tests at the study location (in-situ) using laboratory-raised organisms; and
- comparing characteristics of organisms at a study location to a reference location.

In this paper, we will briefly discuss how bioassessment techniques are currently used in the Superfund program. This will be followed by a more general discussion of how bioassessments might be more extensively used to support decisions. Finally, we provide some recommendations for further research that will make bioassessment a more effective tool for decision-making.

THE CURRENT USE OF BIOASSESSMENT TECHNIQUES AT SUPERFUND SITES

The use of bioassessment techniques at uncontrolled hazardous waste sites is at a relatively early stage of development. The use of these techniques is not specifically

required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA). However, Section 104 of CERCLA does authorize investigations, monitoring, surveys, testing, and other information gathering as necessary or appropriate to identify the existence and extent of a release or threatened release, and the extent of danger to the environment.

Bioassessment techniques may be useful at many stages of the Superfund process. Specifically, the studies may be used as a monitoring tool to detect the presence of hazardous materials to determine if remedial action is needed, to gauge the areal extent of required remedial action, to evaluate alternative remedial actions, and to assess and characterize the risks posed by releases from the waste sites. Additionally, bioassessments can be used both during and after remedial action to evaluate the efficacy of cleanup activities.

Two examples of how bioassessment techniques have been used at Superfund sites are discussed in the remainder of this section. More examples of bioassessment applications at hazardous waste sites can be found in U.S. EPA, 1989a, b, c, and d. These examples are described here to provide a foundation for the more general discussion of bioassessment and risk assessment in the following sections of the paper.

The first example is work done at the Rocky Mountain Arsenal near Denver (U.S. EPA, 1987). This site was used principally by the U.S. Army and by Shell Chemical Co. to manufacture, test, and dispose of toxic chemicals, including pesticides and chemical warfare agents. Preliminary testing indicated that an area referred to as Basin A was contaminated, and suggested that a gradient in contamination extended north-south from a trench that drains Basin A. Therefore a sampling design consisting of four parallel transects extending south from the trench was used. Soil samples were collected and a battery of toxicity tests were conducted using the soil and elutriates of the soil.

Toxic effects were exhibited primarily in lettuce seed germination and lettuce root elongation tests. Little toxic effect was seen in Daphnia, Microtox, or algal toxicity tests using the elutriates, indicating the toxicants probably do not leach readily from the soil. Based on lettuce seed mortality tests, contour maps were developed for the 0- to 15-cm soil fraction (shown in Figure 1) and also for the 15- to 30-cm soil fraction.

Based on these results, a 30% lettuce mortality was selected as a criterion for cleanup of the Basin A site. The 30% criterion was selected because it was two standard deviations above the mean control mortality. Using this criterion, the shaded areas below the heavy black line in Figure 1 would be selected for cleanup.

Another example of the use of bioassessment techniques at a hazardous waste site is a study conducted at a wood treatment plant in Mississippi which was known to be contaminated with creosote and other wood-preserving materials (U.S. EPA, 1987). An exploratory study was designed to determine whether toxicity

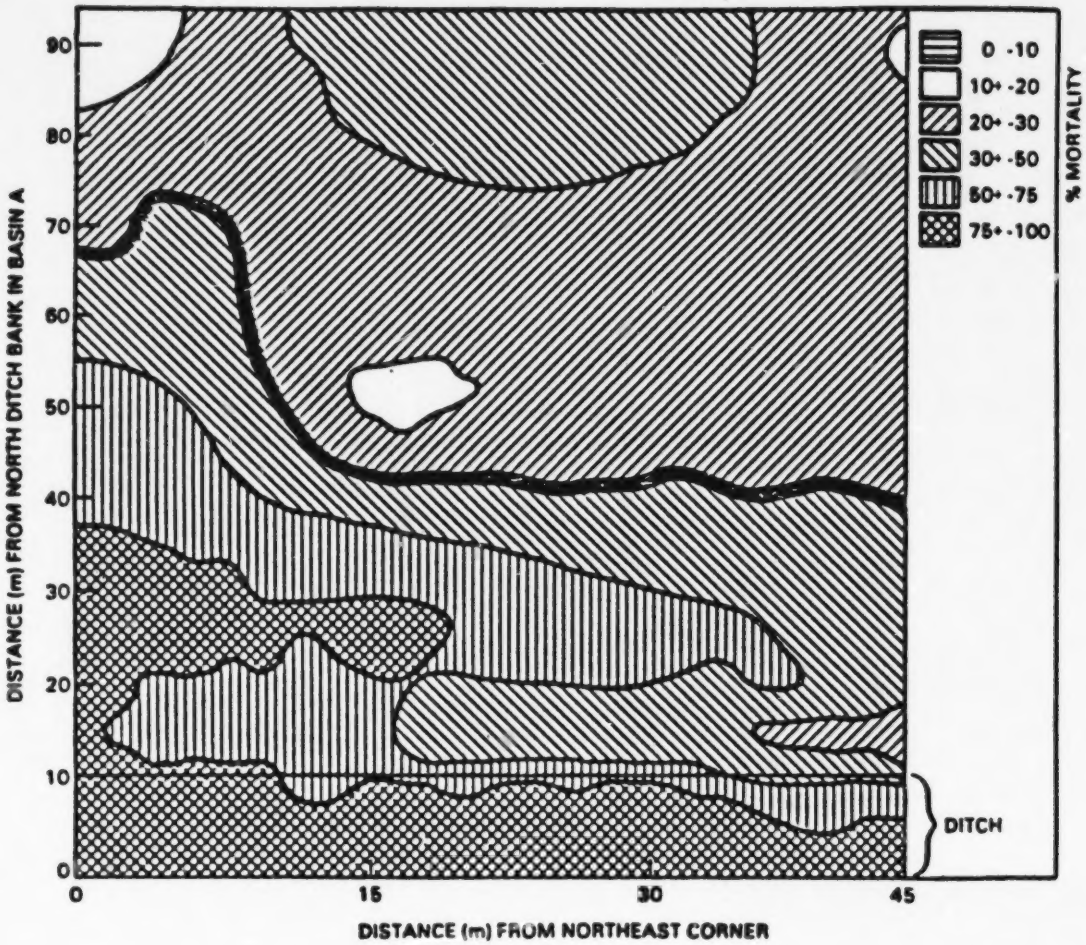

Figure 1. Estimated lettuce seed mortality (based on kriging) for the 15- to 30-cm soil fraction from the Rocky Mountain Arsenal

Source: U.S. EPA, 1987

tests could be used to detect creosote contamination in stream sediments and water and to define the boundaries of contaminated zones on the site.

Sediment and water samples were collected for use in bioassays on the site upstream and downstream of a visibly contaminated zone, with an additional control sample upstream of the site. Figure 2 shows the results from sediment toxicity tests using four different organisms as well as chemical analysis of creosote concentrations. The chemical analysis showed the highest creosote concentrations in the furthest downstream portion of the creek study area. Although the toxicity tests showed somewhat variable results, the algae, Daphnia, and Microtox bioassays showed the greatest adverse responses in samples taken from upstream of the highest creosote concentrations. These results indicated that contaminants other than creosote may be present in the stream sediments. The Microtox bioassay, and to a lesser extent the Daphnia bioassay, also exhibited toxic effects in the area of detectable creosote contamination. Based on the results of the

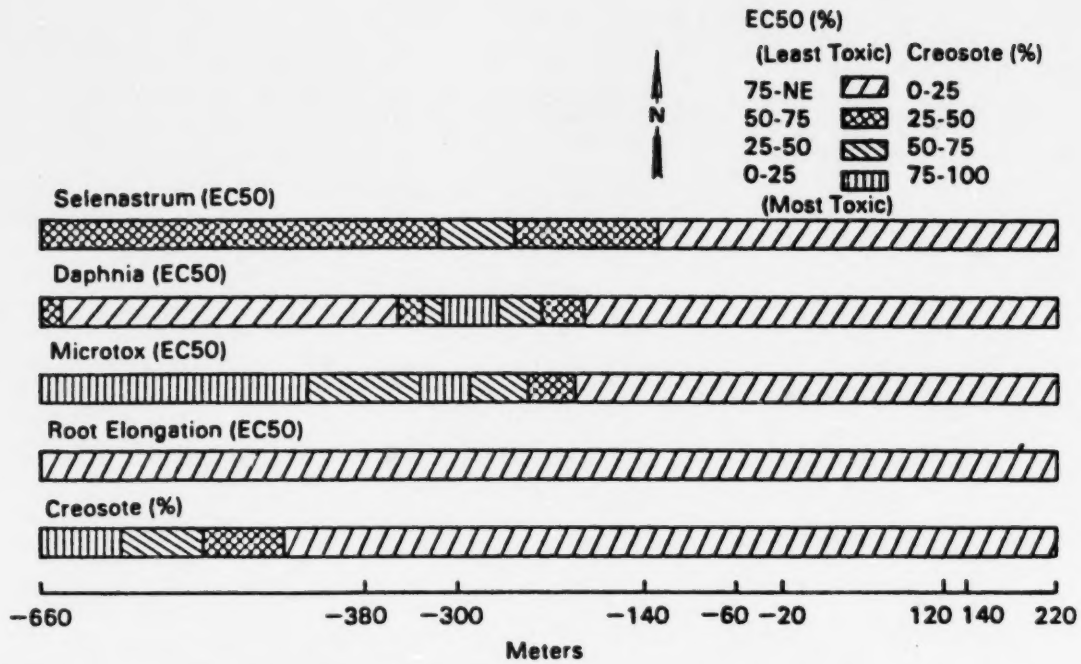

Figure 2. Bioassay results from sediment elutriates at a wood treatment site in Mississippi. Negative numbers represent samples collected downstream from the site

Source: U.S. EPA, 1987

toxicity tests, it was recommended that cleanup should begin about 220 m west of the initial point and continue to about the 660-m area.

As can be seen in the previous examples, bioassessment can be a very useful tool for evaluating complex wastes. Although it is beyond the scope of this paper, there are many available techniques that are either readily usable or easily adaptable for routine use (e.g., U.S. EPA, 1983; Greene et al., 1988; U.S. EPA, 1989). However, bioassessment still has not made the transition from a research technique that is used only under special circumstances to a tool that can be routinely used to support decisions at hazardous waste sites. To gain some insight into this transition, it is worth examining how the Agency makes decisions.

APPLICATIONS OF BIOASSESSMENT IN RISK ASSESSMENT

The Agency makes many of its decisions aimed at protecting human health and the environment using a framework called risk assessment (Figure 3). EPA's risk assessment process consists of a series of steps: (1) identify the adverse effects caused by a material (hazard identification), (2) characterize the relationship between exposure to the material and the extent of adverse effects (dose- or exposure-response assessment), (3) assess the extent of exposure to the material, and (4) combine the results of the first three steps to characterize the probability of adverse effects occurring in the environment (U.S. EPA, 1984). The first two steps of this process, hazard

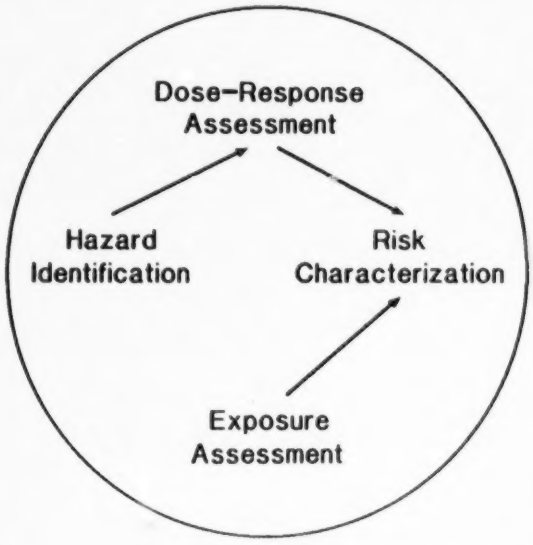

Figure 3. Risk assessment

identification and exposure-response assessment, are often referred to together as the toxicity assessment component of risk assessment.

Risk assessments are commonly conducted for individual chemicals. There are some distinct advantages to assessing risk on a chemical-specific basis. Chemical analyses are essential for identifying a specific pollutant, such as an EPA priority pollutant, or when conforming to an established chemical-specific regulatory standard. Chemical analyses may be more cost-effective when characterizing simple wastes containing few chemicals. Finally, many treatment systems are developed specifically to manage a particular chemical. Chemical-specific analyses provide a common currency that can be easily communicated to the engineers and chemists who operate the facility or design the treatment system.

Bioassessment techniques, however, offer some advantages over chemical analysis. Because bioassessment can directly measure effects of a contaminated medium on biota, it incorporates a measure of bioavailability (i.e., desorption from the medium and subsequent uptake by the organism). In addition, bioassessment techniques evaluate the combined toxicity of all components of a complex waste mixture or medium. This is a definite advantage in that some toxic chemicals may not be detected by routine chemical analyses. While chemical analyses can be conveniently compared with guidelines or standards, such benchmarks are not available for all toxic chemicals potentially present in hazardous wastes or effluents. Finally, for complex wastes, conducting a select group of bioassessments may be more cost-effective than completely characterizing chemical content.

Bioassessment techniques can be readily applied to all of the different components of the risk assessment paradigm (Figure 4). Currently, however, bioassessment techniques are used most frequently for two purposes in site assessments. First, they are used at the beginning of the process when

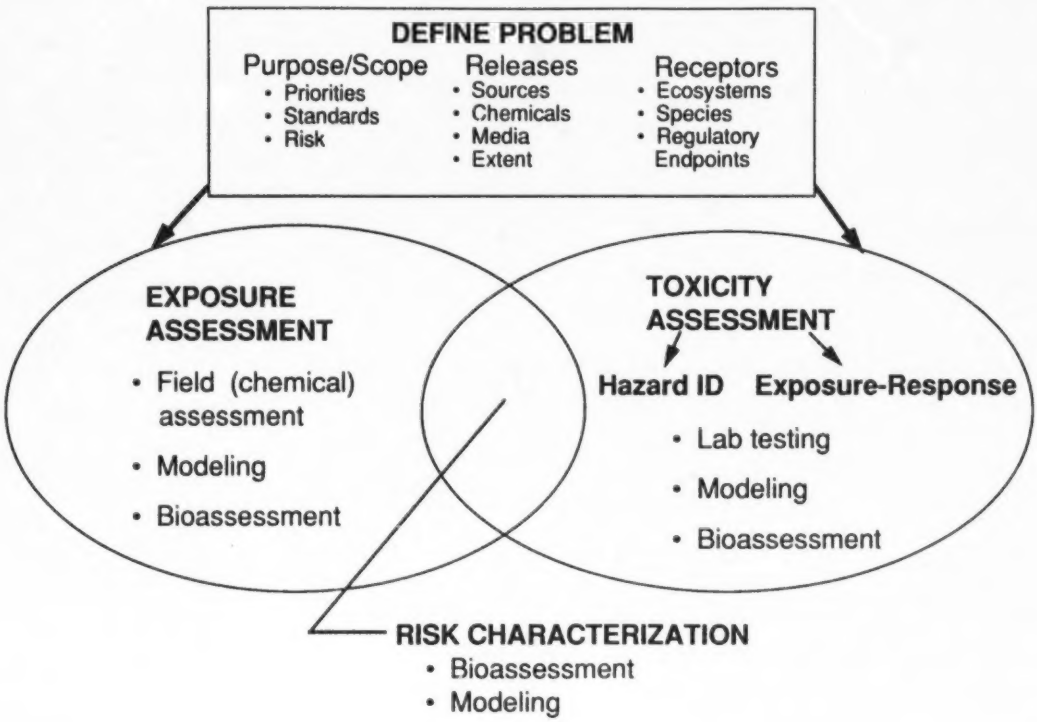

Figure 4. Ecological risk assessment

identifying potential problems. In particular, bioassessment has been used to define the extent of contamination at sites, as illustrated by the bioassays conducted at the Rocky Mountain Arsenal site. Second, as illustrated by the creosote example, bioassessment techniques have been used to directly characterize risk by measuring adverse effects in organisms on the site or exposed (in a laboratory) to media from the site.

TOXICITY ASSESSMENT AND REMEDIAL DECISIONS

Bioassessment techniques have been used less often as tools for the exposure and toxicity assessment components of risk assessment. It is especially important to develop bioassessment techniques for the toxicity assessment component of risk assessment. While the risk characterization part of risk assessment indicates whether remedial action is necessary at all, it is the toxicity assessment that provides more specific guidance for risk reduction decisions (Figure 5)..

As discussed previously, toxicity assessment consists of two steps, hazard identification and exposure-response assessment. The adverse effects potentially caused by a chemical are identified in the hazard identification step. The definition of what constitutes an adverse effect is not necessarily an easy task. For the decision-maker, an adverse effect is what he or she is trying to protect against, for example, increased cancer in humans, or a decrease in a population of sportfish. Suter (in U.S. EPA, 1989e) has called the adverse effects important to decision-makers "assessment endpoints." Unfortunately, it is often difficult or impossible

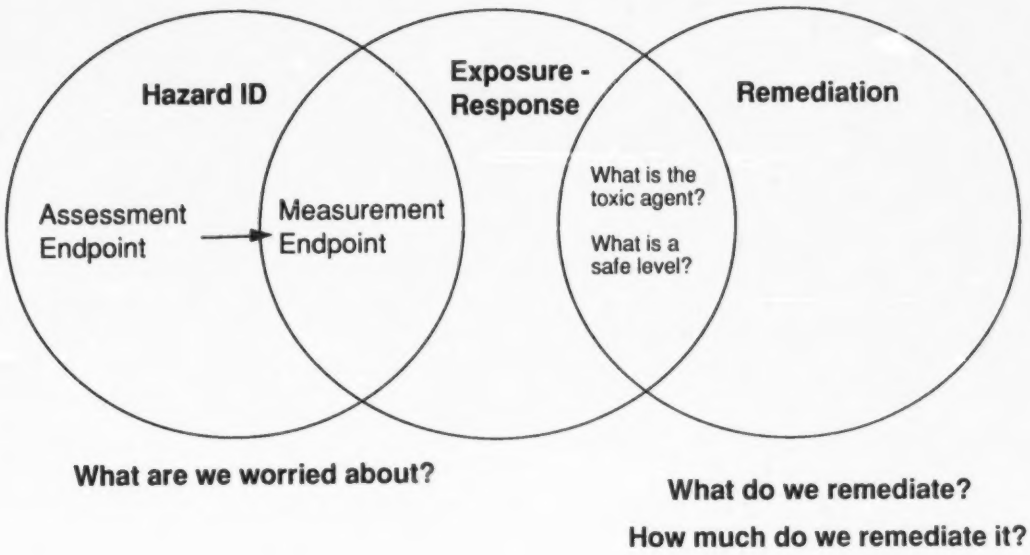

Figure 5. Toxicity assessment and remedial decisions

to measure changes in assessment endpoints. Hence, the scientist documenting adverse effects will measure changes in "measurement endpoints," for example, reproductive impairment in fish or cancer incidence in laboratory animals. The measurement endpoint is the "response" in the exposure-response characterization step of risk assessment. The "exposure" part of the exposure-response characterization defines what toxic agent is being considered, for example, a chemical, a mixture, or a contaminated medium. This is an important step in that it identifies what will be targeted for remediation. The exposure-response curve itself provides the pivotal information that is used to identify acceptable levels of exposure.

There are many other factors that are considered in making a risk reduction decision, including engineering constraints and cost-benefit trade-offs. However, it is the toxicity assessment part of the risk assessment process that answers the health-based questions: What are we worried about?, What do we remediate?, and How much do we remediate it?

RECOMMENDATIONS

Some recommendations for future directions and emphases in bioassessment research can be made based on the previous discussion. One recommendation is to expand techniques for identifying toxic agents. Currently, toxic agents are most often characterized by chemically analyzing the medium concurrently with bioassessment. Conducting bioassays on fractions of waste or effluent is another possible way to focus in on the toxic components. The important consideration here is to communicate what exactly needs to be remediated to the engineers and scientists designing treatment systems or remedial alternatives. For example, biomarkers may be a powerful way to measure exposure to a contaminant. However, if exposure as measured by a biomarker cannot be related to

something that can be treated, the biomarker will be of limited use in choosing remedial options.

A second recommendation is to expand techniques for obtaining exposure-response relationships. For example, media-based exposure-response curves can be constructed by diluting the medium being tested to provide a range of contaminant concentration. Another way to obtain a range of concentration is to locate a gradient on a site. An exposure-response curve could also be obtained by conducting tests sequentially during the course of remediation. As bioassessment techniques are used more frequently to evaluate the efficacy of remedial activities, tests conducted before and during remediation will provide a needed baseline for comparison.

One final recommendation is to continue to solidify links between measurement endpoints and assessment endpoints. Unless we can connect what EPA is mandated to protect (e.g., environmental health) with what we can measure, risk reduction actions based on bioassessment will be difficult to support.

Measurement and assessment endpoints can be linked both qualitatively and quantitatively. Qualitatively, connections can be made using our knowledge of environmental systems. While these relationships may be common sense for ecologists, they must be communicated effectively to the people making the decisions. For example, while a decision-maker may not base a remedial decision on possible adverse effects to Daphnia per se, they may base a decision on possible adverse effects to the food web of an important community. The idea of using certain species as sentinel or indicator organisms is certainly not new; we have used canaries in coal mines to monitor air quality and trout in cold-water streams to monitor water quality. However, careful reasoning may be required to base the selection of a costly remedial alternative on, for example, mortality in earthworms. Quantitatively, we can clarify connections between assessment and measurement endpoints by continuing efforts in ecosystem modeling. For example, models developed at the Oak Ridge National Laboratory use information on effects on individual species to predict effects at the community level (e.g., SWACOM in Barnthouse et al., 1986).

Bioassessment techniques will undoubtedly be used to a greater degree in the future as a tool in environmental research. Unfortunately, the development of methods for bioassessment has outpaced the ability of many decision-makers to easily interpret the implications of their results. It is important for scientists to continue developing and refining bioassessment techniques. However, it is also essential that we continue to search for ways to make bioassessments more interpretable, applicable, and useful in supporting environmental decisions.

REFERENCES

Barnthouse, L.W., Suter, G.W., Bartell, S.M., Beauchamp, J.J., Gardner, R.H., Linder, E., O'Neill, R.V., and Rosen, A.E., 1986, "User's Manual for Ecological Risk Assessment." Environmental Sciences Division Publication No. 2679. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

National Research Council (NRC), 1983, "Risk Assessment in the Federal Government: Managing the Process." National Academy Press, Washington, D.C.

U.S. Environmental Protection Agency (U.S. EPA), 1983, "Protocol for Bioassessment of Hazardous Waste Sites." EPA 600/2-83-054. Environmental Research Laboratory, Corvallis, OR.

U.S. Environmental Protection Agency (U.S. EPA), 1984, "Risk Assessment and Management: Framework for Decision Making." EPA 600/9-85-002, PB85-170157.

U.S. Environmental Protection Agency (U.S. EPA), 1987, "Role of Acute Toxicity Bioassays in the Remedial Action Process at Hazardous Waste Sites." EPA/600/8-87/044. Environmental Research Laboratory, Corvallis, OR.

U.S. Environmental Protection Agency (U.S. EPA), 1988, "Protocols for Acute Toxicity Screening of Hazardous Waste Sites. Final Draft." Environmental Research Laboratory, Corvallis, OR.

U.S. Environmental Protection Agency (U.S. EPA), 1989a, "Summary of Ecological Risks, Assessment Methods, and Risk Management Decisions in Superfund and RCRA." EPA 230/03-89-046.

U.S. Environmental Protection Agency (U.S. EPA), 1989b, "The Nature and Extent of Ecological Risks at Superfund Sites and RCRA facilities." EPA 230/03-89-043.

U.S. Environmental Protection Agency (U.S. EPA), 1989c, "Ecological Risk Assessment Methods: a Review and Evaluation of Past Practices in the Superfund and RCRA Programs." EPA 230/03-89-044.

U.S. Environmental Protection Agency (U.S. EPA), 1989d, "Ecological Risk Management in the Superfund and RCRA Programs." EPA 230/03-89-045.

U.S. Environmental Protection Agency (U.S. EPA), 1989e, "Ecological Assessment of Hazardous Waste Sites." EPA 600/3-89/013. Environmental Research Laboratory, Corvallis, OR.